Summary

SUMMARY

The U.S. Department of Energy (DOE, or the Department) issued the *Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (Draft EIS), dated July 1999, in accordance with the National Environmental Policy Act of 1969, as amended (42 USC 4321 *et seq.*), and the Nuclear Waste Policy Act, as amended (42 USC 10101 *et seq.*). The Draft EIS describes the Proposed Action to construct, operate and monitor, and eventually close a repository at Yucca Mountain, and the potential environmental impacts of that action.

For the Draft EIS, DOE based the analysis on a design described in the *Viability Assessment of a Repository at Yucca Mountain* to estimate potential environmental impacts from the Proposed Action. The Draft EIS discussed ongoing evaluations (see page 2-10 of the Draft EIS for an example) that could result in modifications to that design.

As DOE anticipated in the Draft EIS, the repository design has continued to evolve, reflecting evaluations of design options and ways in which to operate the repository (operating modes) that would reduce uncertainties and improve long-term performance and operational safety and efficiency. DOE has documented the evolution of the design in the *Yucca Mountain Science and Engineering Report: Technical Information Supporting Site Recommendation Consideration*, which describes the current design (which this Supplement calls the *S&ER flexible design*) and a range of possible repository operating modes and summarizes technical information that the Secretary of Energy will use to determine whether to recommend approval of the Yucca Mountain site to the President for development as a repository. The fundamental aspects of the repository design have not changed from the design discussed in the Draft EIS.

The S&ER flexible design includes the ability to operate the repository in a range of operating modes that address higher and lower temperatures and associated humidity conditions. *Higher-temperature* means that at least a portion of the emplacement drift rock wall would have a maximum temperature above the boiling point of water at the elevation of the repository [96ºC (205ºF)]. The *lower-temperature* operating mode ranges include conditions under which the drift rock wall temperatures would be below the boiling point of water, and conditions under which the waste package surface temperature would not exceed 85ºC (185ºF). To bound the impact analysis, DOE considered conditions under which the rock wall temperatures would be above the boiling point of water, and conditions under which waste package surface temperatures would not exceed 85ºC.

DOE prepared this Supplement to update information presented in the Draft EIS. The Supplement evaluates potential environmental impacts that could occur, based on the design and range of possible operating modes of the S&ER flexible design. In addition, the Supplement compares these impacts to the impacts presented in the Draft EIS.

The basis for the analytical scenarios presented in the Draft EIS was the amount of commercial spent nuclear fuel and its associated thermal output or load that DOE would emplace per unit area of the repository (called *areal mass loading*). In the Draft EIS, DOE evaluated three thermal load scenarios including *high thermal load*, a relatively high emplacement density of commercial spent nuclear fuel [85 metric tons of heavy metal (MTHM) per acre], *intermediate thermal load* (60 MTHM per acre), and *low thermal load* (25 MTHM per acre). The analytical scenarios described in the Draft EIS were not intended to place a limit on the choices among alternative designs because DOE expected that the repository design would continue to evolve. Rather, DOE selected these scenarios to represent the range of foreseeable design features and operating modes and to ensure that it considered the associated range of potential environmental impacts.

In contrast to focusing on thermal loads, the S&ER flexible design focuses on controlling the temperatures of the rock between the drifts, of the waste package surfaces, and of the drift walls to meet thermal management goals established for possible repository operating modes. To meet these thermal goals, the S&ER flexible design uses a *linear thermal load* (heat output per unit length of the emplacement drift) and emplaces waste packages relatively closer together than the Draft EIS design. Linear thermal load is expressed in terms of kilowatts per meter.

As with the thermal load analytical scenarios analyzed in the Draft EIS, the range of operating modes under the S&ER flexible design is representative of the range of foreseeable future design features and operating modes, and the conservative estimates of the associated potential environmental impacts in this Supplement encompass or bound the potential impacts of foreseeable future repository design evolution.

This Supplement focuses on modifications to the repository design and operating modes addressed in the Draft EIS; it does not analyze aspects of the Proposed Action that have not been modified, such as the transportation of spent nuclear fuel and high-level radioactive waste, or the No-Action Alternative. DOE will address the Proposed Action and the No-Action Alternative fully in the Final EIS. In addition, DOE will consider comments on the Draft EIS and on this Supplement in the Final EIS.

Because the repository design has evolved from that considered in the Draft EIS, the Final EIS will evaluate only the S&ER flexible design, including the reasonable range of operating modes, and any enhancements to the flexible design developed as the result of ongoing analyses. DOE invites comments on its intention not to address the Draft EIS design in the Final EIS.

S.1 S&ER Flexible Design

Under the Proposed Action, DOE would permanently place approximately 11,000 to 17,000 waste packages containing no more than 70,000 metric tons of heavy metal (MTHM) of spent nuclear fuel and high-level radioactive waste in a repository at Yucca Mountain.

The S&ER flexible design, which is the basis for this Supplement, includes the following modifications from the design evaluated in the Draft EIS:

- Expanded the capability of the Waste Handling Building to blend hotter and cooler commercial spent nuclear fuel assemblies to control the heat generation of the waste packages

- Added flexibility to include surface aging (or cooling) of hotter commercial spent nuclear fuel to control the heat of the waste packages

- Modified the subsurface design to enable a cooler repository, including increased ventilation

- Added a solar power generating facility to reduce the need for power from off the site

- Revised emplacement drift layout to increase drift stability

- Increased spacing between emplacement drifts to allow a moisture pathway between the drifts

- Added operational flexibility to vary the spacing between waste packages in a drift to manage the heat load

- Added drip shields of corrosion-resistant titanium over the waste packages to divert moisture

- Refined the waste package to incorporate a more corrosion-resistant outer shell (Alloy-22) and structural stainless-steel inner shell to improve overall performance
- Modified ground support in emplacement drifts to reduce uncertainties associated with changes in water chemistry (replaced concrete liner with steel sets)
- Modified the invert, which includes the structures and materials that form a platform to support the pallet and waste package, to a steel structure with ballast (fill) (replaced the concrete invert due to the potential long-term impacts of concrete alkalinity)
- Replaced waste package pedestals (supports) with corrosion-resistant pallets (Alloy-22) to improve waste package handling and reduce the potential for corrosion between the waste package and the pallet

The purpose of these modifications is to improve the long-term performance, operational safety, and efficiency of the proposed repository, and to reduce the uncertainties related to high (above-boiling) repository host rock temperatures. Modifications associated with waste package loading, waste package spacing, and ventilation are primary operational parameters because DOE could vary them to facilitate control of the maximum emplacement drift wall temperature at a point above or below the boiling point of water or control the average maximum surface temperatures of the waste packages, depending on the target thermal management goals. Table S-1 summarizes the key underground design and operating parameters associated with the repository operating modes analyzed in this Supplement and, for comparative purposes, the thermal loads presented in the Draft EIS.

Table S-1. Key underground design and operating parameters associated with thermal load scenarios and repository operating modes.

Parameter	Unit of measure	Draft EIS thermal load scenarios			S&ER flexible design operating mode	
		Low	Intermediate	High	Higher-temperature	Lower-temperature
Variable parameter						
Areal mass load	MTHM[a] per acre	25	60	85	56	25 to 56
Linear thermal load	Kilowatts per meter	(b)	(b)	(b)	1.42	0.5 to 1.0
Drift spacing	Meters	38	40	28	81	81[c]
Waste package spacing	Meters	22	5	5	0.1	0.1 to 6.4[c]
Emplacement duration	Years	24	24	24	24	24 (50)[d]
Closure duration	Years	15	6	6	10	12 to 17
Preclosure ventilation duration[e]	Years	100	100	100	100	149 to 324
Ventilation rate (forced)	Cubic meters per second in drift	0.1	0.1	0.1	15	15
External ventilation shafts (emplacement and development)	Number	5	2	2	7	9 to 17
Dependent parameter						
Underground area	Square kilometers	10.0	4.25	3.0	4.7	6.5 to 10.1
Total excavated repository volume[f]	Millions of cubic meters	14.0	5.7	4.8	4.4	5.7 to 8.8
Waste packages	Number (in thousands)	10 to 11	10 to 11	10 to 11	11 to 12	11 to 17

a. MTHM = metric tons of heavy metal.
b. The Draft EIS design did not consider linear thermal load; both waste package heat output and spacing were highly variable.
c. Drift spacing and waste package spacing would determine various areal mass loads.
d. The lower-temperature repository operating mode analysis assumed that waste emplacement with commercial spent nuclear fuel aging would occur over a 50-year period ending in 2060.
e. From start of emplacement to start of repository closure.
f. Includes existing Exploratory Studies Facility volume of 0.42 million cubic meters.

S.2 Evaluation of Impacts

This Supplement evaluates how potential impacts associated with the S&ER flexible design compare to the impacts described for the 13 environmental resource areas presented in Chapter 4 of the Draft EIS. In addition, it compares the long-term performance impacts of the S&ER flexible design to those presented in Chapter 5 of the Draft EIS. Finally, because the S&ER flexible design includes drip shields and emplacement pallets, which the design evaluated in the Draft EIS did not, this Supplement evaluates the material requirements for those items and the impacts of transporting them to Yucca Mountain.

As part of its evaluation, DOE selected *primary impact indicators* in each environmental resource area. Primary impact indicators are the most important contributors or parameters used to determine specific impacts in an environmental resource area. They are directly proportional to the specific impact, and are generally determined during an intermediate step in the impact calculation or evaluation. In some environmental resource areas—for example, those that involved the highest annual impacts—DOE selected primary impact indicators to focus the evaluation on the single project phase (such as construction) that would result in the highest impacts. The use of these indicators enables a comparison between impacts of the S&ER flexible design and those presented in the Draft EIS. The Department used the ratio of primary impact indicators to specific impacts in the Draft EIS to determine the Supplement impact estimates.

Table S-2 summarizes the environmental impacts resulting from the design evolution, as described in Chapter 3. This information indicates that, for many environmental resource areas, there would appear to be increases in the short-term impacts associated with the S&ER flexible design in comparison to those described in the Draft EIS. These increases reflect the use of the maximum operating parameters associated with the lower-temperature repository operating mode. Section 2.1.5.2 of the *Yucca Mountain Science and Engineering Report: Technical Information Supporting Site Recommendation Consideration* provides a set of sample operating scenarios, each of which would be low temperature, that exhibits the design's inherent flexibility. To perform an evaluation of the environmental impacts of the lower-temperature mode, DOE maximized each of the three primary operating parameters in turn, while assigning the remaining two parameters with the corresponding proportional values that enabled meeting the lower-temperature operating mode criteria. This Supplement reports the results of this evaluation as a range of environmental impacts, dependent on the particular operating parameter maximized for the analysis. DOE expects that the environmental impacts for the lower-temperature operating mode would fall somewhere within the ranges presented for all areas evaluated.

Changes to the cumulative impacts described in the Draft EIS would be proportional to the changes between Draft EIS impacts and those discussed in Chapter 3 of this Supplement.

Table S-2. Environmental impacts associated with the S&ER flexible design[a] (page 1 of 3).

Environmental resource area	Primary impact indicator	Draft EIS scenarios	S&ER flexible design operating mode	
			Higher-temperature	Lower-temperature
Land use and ownership	Land withdrawal	Withdraw about 600 km^2 of land under Federal control; active use of about 3.3 to 3.5 km^2.	Withdraw about 600 km^2 of land under Federal control; active use of about 4.3 km^2.	Withdraw about 600 km^2 of land under Federal control; active use of about 4.9 to 8.1 km^2.
Air quality	Radiological (Radon release, radon and decay products would account for more than 99 percent of the potential radiation dose to members of the public.)	Release 110,000 to 340,000 curies over project life (111 to 120 years). Highest dose to offsite MEI would be 1.8 millirem per year. For exposed population, projected 0.14 to 0.41 LCF.	Release 170,000 curies over project life (115 years). Highest dose to offsite MEI would be about 1.2 millirem per year. For exposed population, projected 0.22 LCF.	Release 390,000 to 800,000 curies over project life (171 to 345 years). Dose to offsite MEI would be about 1.7 to 2.6 millirem per year. For exposed population, projected 0.49 to1.0 LCF.
	Particulate matter	Release 170,000 to 180,000 kg of fugitive dust during highest year. Highest air concentration would be no more than 1.4% of the NAAQS PM_{10} annual standard of 50 mg/m^3.	Release 220,000 kg of fugitive dust during highest year. Highest air concentration would be no more than 1.7% of the NAAQS PM_{10} annual standard of 50 mg/m^3.	Release 320,000 to 380,000 kg of fugitive dust during highest year. Highest air concentration would be no more than 1.9 to 2.9% of NAAQS PM_{10} annual standard of 50 mg/m^3.
	Gaseous pollutants (NO_2 as representative)	Release 130,000 to 230,000 kilograms of NO_2 during the highest year. Highest air concentration would be no more than 0.83% of the NAAQS NO_2 annual standard of 100 mg/m^3.	Release 87,000 kg of NO_2 during highest year. Highest air concentration would be no more than 0.31% of NAAQS NO_2 annual standard of 100 mg/m^3.	Release 88,000 to 96,000 kg of NO_2 during highest year. Highest air concentration would be no more than 0.31 to 0.34% of the NAAQS NO_2 annual standard of 100 mg/m^3.
Hydrology	Water use (groundwater)	Water demand of 250 to 480 acre-feet per year would be less than lowest estimate of perennial yield (580 acre-feet per year).	Water demand of 230 acre-feet per year would be less than lowest estimate of perennial yield (580 acre-feet per year).	Water demand of 240 to 360 acre-feet per year would be less than lowest estimate of perennial yield (580 acre-feet per year).
	Disturbed area (surface water)	Disturbed area of 3.3 to 3.5 km^2.	Disturbed area of about 4.3 km^2.	Disturbed area of 4.9 to 8.1 km^2.
Biological resources	Disturbed area	Loss of 3.3 to 3.5 km^2 total, 1.8 to 2 km^2 newly disturbed area of desert soil, habitat, and vegetation. Adverse impacts to desert tortoise (individuals). Small impacts to other plants, animals, and habitat. Small impacts to wetlands.	Loss of about 4.3 km^2 total, 2.8 km^2 newly disturbed area of desert soil, habitat, and vegetation. Adverse impacts to desert tortoise (individuals). Small impacts to other plants, animals, and habitat. Small impacts to wetlands.	Loss of about 4.9 to 8.1 km^2 total, 3.4 to 6.6 km^2 newly disturbed area of desert soil, habitat, and vegetation. Adverse impacts to desert tortoise (individuals). Small impacts to other plants, animals, and habitat. Small impacts to wetlands.
Cultural resources	Newly disturbed area	Disturbance of 3.3 to 3.5 km^2 total area, with 1.8 to 2 km^2 newly disturbed. Opposing Native American viewpoint.	Disturbance of about 4.3 km^2 total area, with 2.8 km^2 newly disturbed. Location of solar power generating facility could create potential for affecting archaeological sites. Opposing Native American viewpoint.	Disturbance of about 4.9 to 8.1 km^2 total area, with 3.4 to 6.6 km^2 newly disturbed. Location of solar power generating facility could create potential for affecting archaeological sites. Opposing Native American viewpoint.

Table S-2. Environmental impacts associated with the S&ER flexible design[a] (page 2 of 3).

Environmental resource area	Primary impact indicator	Draft EIS scenarios	S&ER flexible design operating mode	
			Higher-temperature	Lower-temperature
Socioeconomics	Direct work force	Small increases in direct (47,000 worker-years through 2033) and indirect jobs from Yucca Mountain activities—less than 1%—compared to normal growth and impacts for Nye, Clark, and Lincoln Counties. Small impacts to population, economic measures, housing, and public services.	Small increases in direct (49,000 worker-years through 2033) and indirect jobs from Yucca Mountain activities compared to normal growth and impacts for Nye, Clark, and Lincoln Counties. Small impacts to population, economic measures, housing, and public services.	Small increases in direct (50,000 to 53,000 worker-years through 2033) and indirect jobs from Yucca Mountain activities compared to normal growth and impacts for Nye, Clark, and Lincoln Counties. Small impacts to population, economic measures, housing, and public services.
Occupational safety and health	Total workers	63,000 to 67,000 (worker-years) over project life. About 1.8 to 2 fatalities from industrial accidents.	68,000 worker-years over the project life. About 2 fatalities from industrial accidents.	77,000 to 98,000 worker-years over project life. About 2.2 to 2.8 fatalities from industrial accidents.
	Radiologically exposed workers	Impacts to individual workers limited by regulatory and administrative dose limits. Potential impacts to worker population over project life would be 3.7 to 4.3 LCFs from radiation exposure.	Impacts to individual workers limited by regulatory and administrative dose limits. Potential impacts to worker population over project life would be 4.2 LCFs from radiation exposure.	Impacts to individual workers limited by regulatory and administrative dose limits. Potential impacts to worker population over project life would be 5.1 to 6.9 LCFs from radiation exposure.
Accidents	Consequences of most severe reasonably foreseeable (bounding) accident	Impacts of bounding facility accident would be 1.6×10^{-5} probability of LCF in individual, and 7.2×10^{-3} probability of LCF in exposed population.	Impacts of bounding facility accident would be 1.3×10^{-5} probability of LCF in individual, and 5.6×10^{-3} probability of LCF in exposed population.	Impacts of bounding facility accident would be a 1.3×10^{-5} probability of LCF in individual, and 5.6×10^{-3} probability of LCF in exposed population.
Noise	Sound levels	Impacts to public would be low due to large distances to publicly accessible areas. Workers exposed to elevated noise levels; controls and protection used as necessary.	Impacts to public would be low due to large distances to publicly accessible areas. Workers exposed to elevated noise levels; controls and protection used as necessary.	Impacts to public would be low due to large distances to publicly accessible areas. Workers exposed to elevated noise levels; controls and protection used as necessary.
Aesthetics	Visual impacts	Low adverse impacts to aesthetic or visual resources in region.	Low adverse impacts to aesthetic or visual resources in region.	Low adverse impacts to aesthetic or visual resources in region.
Utilities, energy, and materials	Electric power use	5,900 to 9,400 GWh over project life.	11,000 GWh over project life.	24,000 to 32,000 GWh over project life.
	Peak electrical demand	Peak demand of 41 MW. Enhanced electric power delivery system to site.	Peak demand of 47 MW. Enhanced electric power delivery system to site.	Peak demand of 47 to 57 MW. Enhanced electric power delivery system to site.
	Fossil fuel	300 to 390 million liters over project life. Small use in comparison to amounts available in region.	390 million liters over project life. Small use in comparison to amounts available in region.	420 to 620 million liters over project life. Small use in comparison to amounts available in region.
	Concrete	800,000 to 2,100,000 metric tons over project life. Small use in comparison to amounts available in region.	660,000 metric tons over project life. Small use in comparison to amounts available in region.	830,000 to 1,700,000 metric tons over life of project. Small use in comparison to amounts available in region.
	Steel	210,000 to 810,000 metric tons over project life. Small use in comparison to amounts available in region.	160,000 metric tons over project life. Small use in comparison to amounts available in region.	210,000 to 310,000 metric tons over project life. Small use in comparison to amounts available in region.

Table S-2. Environmental impacts associated with the S&ER flexible design[a] (page 3 of 3).

Environmental resource area	Primary impact indicator	Draft EIS scenarios	S&ER flexible design operating mode	
			Higher-temperature	Lower-temperature
Utilities, energy, and materials (continued)	Copper	0.2 to 1.0 thousand metric tons over project life. Small use in comparison to amounts available in region.	0.2 thousand metric tons over project life. Small use in comparison to amounts available in region.	0.3 to 0.5 thousand metric tons project life. Small use in comparison to amounts available in region.
Waste generation	Construction and demolition debris	150,000 m^3 over project life, requiring disposal in a new onsite landfill or as much as about 15% of NTS landfill capacity.	220,000 m^3 over project life, requiring disposal in a new onsite landfill or as much as 22% of NTS landfill capacity.	220,000 to 810,000 m^3 over project life, requiring disposal in a new onsite landfill or as much as 22 to 82% of NTS landfill capacity. Upper range could require capacity and service life expansion.
	Hazardous waste	7,700 m^3 over project life, small fraction of available disposal capacity.	8,400 m^3 over project life, small fraction of available disposal capacity.	8,400 to 15,000 m^3 over project life, small fraction of available disposal capacity.
	Sanitary and industrial solid waste	85,000 to 110,000 m^3 over project life, 19 to 24% of available NTS disposal capacity.	100,000 m^3 over project life, as much as 22% of available NTS disposal capacity.	110,000 to 190,000 m^3 over project life. 24 to 42% of NTS landfill capacity. Upper range could require capacity and service life expansion.
	Sanitary sewage	2,000 to 2,200 million liters, disposed of in onsite systems.	2,000 million liters, disposed of in onsite systems.	2,300 to 4,100 million liters, disposed of in onsite systems.
	Industrial wastewater	980 to 1,600 million liters, disposed of in onsite systems.	1,000 million liters, disposed of in onsite systems.	1,900 to 3,400 million liters, disposed of in onsite systems.
	Low-level radioactive waste	71,000 m^3 over project life, about 2.3% of available NTS disposal capacity.	71,000 m^3 over project life, about 2.3% of available NTS disposal capacity.	71,000 to 73,000 m^3 over project life, about 2.3 to 2.8% of available NTS disposal capacity.
Environmental justice	Disproportionate impacts	No disproportionately high or adverse impacts to minority or low-income populations. Opposing Native American viewpoint.	No disproportionately high or adverse impacts to minority or low-income populations. Opposing Native American viewpoint.	No disproportionately high or adverse impacts to minority or low-income populations. Opposing Native American viewpoint.
Transportation	Other materials	100 to 140 million km traveled for transporting other material resulting in 3 to 4 traffic fatalities.	100 million km traveled for transporting other material resulting in 3 traffic fatalities.	130 to 190 million km for transporting other material resulting in 4 to 6 traffic fatalities.
	Workers	360 to 450 million km traveled for workers resulting in 3.6 to 4.5 traffic fatalities.	470 million km traveled for workers resulting in 4.7 traffic fatalities.	540 to 680 million km traveled for workers resulting in 5.4 to 6.8 traffic fatalities.
Offsite manufacturing	Titanium	No use of titanium.	43,000 metric tons over project life. Annual use would be less than 8% of U.S. production capacity. Production capacity could be expanded.	43,000 to 60,000 metric tons over project life. Annual use would be less than 8% of U.S. production capacity. Production capacity could be expanded.
Long-term performance	10,000-year peak of the mean annual dose	Dose at 20 km 0.059 to 0.22 millirem.	No dose in the first 10,000 years.	No dose in the first 10,000 years.
	Peak of the mean annual dose (after 10,000 years)	Dose at 20 km 160 to 260 millirem.	Dose at 20 km about 120 millirem.	Dose at 20 km about 120 millirem.
	Time of peak occurrence	Peak of the mean annual dose 340,000 to 800,000 years after closure.	Peak of the mean annual dose 550,000 years after closure.	Peak of the mean annual dose 550,000 years after closure.

a. Abbreviations: GWh = gigawatt-hour; kg = kilograms; km^2 = square kilometers; LCF = latent cancer fatality; m^3 = cubic meter; MEI = maximally exposed individual; mg/m^3 = micrograms per cubic meter; MW = megawatt; NAAQS = National Ambient Air Quality Standards; NO_2 = nitrogen dioxide; NTS = Nevada Test Site; PM_{10} = particulate matter with an aerodynamic diameter of 10 micrometers or less.